Journal of Experimental and Applied Physics
Journal Homepage: jeap.ppj.unp.ac.id
Vol. 2, No. 2, June 2024.
ISSN (Print): 2988-0378 ISSN (Online): 2987-9256

Carbonization Time Optimization In The Preparation Of Coconut Pulp Based Activated Carbon For Thermoelectric Materials

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Article History
Received : June, 17th 2024
Revised : June, 30th 2024
Accepted : June, 30th 2024
Published : June, 30th 2024

DOI:
https://doi.org/10.24036/jeap.v2i2.61

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Abstract: In this study utilizing coconut pulp as an ingredient in making activated carbon for thermoelectric materials From the research that has been done, it is not yet known the best carbonization time on coconut pulp activated carbon for thermoelectric materials. Therefore, this study aims to determine the optimization of carbonization time on coconut pulp activated carbon for thermoelectric materials. The coconut pulp was dried using an oven at 105°C and then carbonized using a furnace. Carbonization time variations used were 10 minutes, 15 minutes, and 20 minutes with temperature variations from previous research, namely 300°C. Then the results of carbonization were mashed using a mortar and pestle and filtered using a 120 mesh sieve. Carbon was activated with 0.5 M HCl (1:10) as much as 25 grams for 24 hours. After activation, the carbon was filtered, washed with distilled water and dried using an oven. Then the coconut pulp activated carbon was characterized by testing water content, vapor content, ash content, and bound carbon content. The test results show that based on SNI 06-3730-1995 the lowest water content is at 10 minutes carbonization time which is 1.72%, the lowest steam content is at 10 minutes carbonization time which is 8.54%, the lowest ash content is at 20 minutes carbonization time which is 0.55%, and the highest bound carbon content is at 10 minutes carbonization time which is 90.65%. The results showed that the optimization of carbonization time on coconut pulp activated carbon for thermoelectric materials was 10 minutes.

Keywords: Activated Carbon, Carbonization Time, Coconut pulp, Thermoelectricity.

1. Introduction

Electrical energy is an energy that is needed by humans today, where almost all human activities require electricity [1]. The need for electricity is increasing along with economic growth

How to cite:
N. Febrian, Y. Darvina, Ramli, R. Hidayat, 2024, Carbonization Time Optimization In The Preparation Of Coconut Pulp Based Activated Carbon For Thermoelectric Materials, *Journal of Experimental and Applied Physics,* Vol.2, No.2, page 112-124. https://doi.org/10.24036/jeap.v2i2.61

and population growth. Various efforts to meet the needs of electrical energy have been made by finding and developing alternative power generation energy sources. Some alternative power generation energy sources such as solar power plants (PLTS), geothermal power plants (PLTG), ocean wave power plants (PLTGL), and thermal power plants using Thermolectric Generators (TEG) [2]. Thermolectric Generator (TEG) is a power plant that works based on the seebeck effect. The working principle of this seebeck effect is that if two different materials are connected to an environment with different temperatures, then in different materials it flows electric current [3]. For Thermoelectric Generators, thermoelectric materials or materials are needed.

Research on composites as thermoelectric materials has been done before, namely Bi2Te3/Graphite/Polythiophene composites [4]. However, the materials used deteriorate at high temperatures, are not environmentally friendly, expensive and difficult to obtain. Therefore, an environmentally friendly, cheap and easily available replacement material is needed, namely a composite of activated carbon with Copper (II) Oxide (CuO). CuO is one of the copper oxide compounds that is suitable for use as a material for making thermoelectric materials because it is environmentally friendly, cheap, easy to obtain and has high electrical conductivity. However, CuO has high thermal conductivity for thermoelectric materials. Therefore, CuO is composited with other materials to lower its thermal conductivity. As a thermoelectric material CuO can be composited with materials such as Activated Carbon, ZnO, Bi2O3, and Sn02. In this study, Activated Carbon will be used to composites with CuO because Activated Carbon has lower thermal conductivity, is environmentally friendly, easily available, and has a high surface area [5].

Research on thermoelectric materials using activated carbon/CuO composites has been carried out previously using coconut shells [6], cocoa shell waste [7], cassava skin waste [1], durian skin waste [8] and coconut fiber [9]. One material that can also be used for activated carbon is coconut pulp. Coconut pulp that continues to be discarded will produce solid waste that can pollute the environment such as polluted water buckets and air pollution from the foul odor it causes. So there needs to be a utilization of coconut pulp that is widely wasted, one of which is as an ingredient in making activated carbon.. In this study the authors used coconut pulp as an ingredient for making activated carbon for thermoelectric materials.

Research on the manufacture of coconut pulp activated carbon has been carried out previously with variations in the type and amount of concentration of activator substance compounds [10]. The study used a carbonization time of 15 minutes and obtained the best activated carbon obtained from using HCl concentration of 0.5 M. Carbonization time can also affect the quality of activated carbon produced, but the best carbonization time optimization for coconut pulp activated carbon is not yet known. Therefore, this study aims to determine the best carbonization time optimization on coconut pulp activated carbon for thermoelectric materials. Carbonization time variations used are 10 minutes, 15 minutes, and 20 minutes. The reason for varying the carbonization time is because carbonization time can affect the quality of activated carbon. Different carbonization times will produce activated carbon with different moisture content, vapor content, ash content and bound carbon content and affect the thermoelectric material properties. This research uses the carbonization temperature from previous research by Aliya Nabila et al, which is 300ºC. Then the coconut pulp activated carbon was characterized, namely testing water content, vapor content, ash content, and bound carbon content. Based on this background, the author wants to examine how to optimize carbonization time in the manufacture of coconut pulp activated carbon for thermoelectric materials.

2. Materials and Method

The research uses an experimental method that aims to determine the optimization of carbonization time in the manufacture of coconut pulp activated carbon for thermoelectric materials. The variables used in the study are independent variables, namely variations in carbonization time of 10 minutes, 15 minutes, 20 minutes. The control variable is the carbonization temperature of 300ºC. The dependent variable is the yield value, water content, vapor content, ash content and bound carbon content. The tools used in this research include a furnace, laboratory oven, desiccator, porcelain cup, mortar and pestle, drop pipette, spatula, beaker, spray bottle, funnel, measuring cup, sieve. The materials used include coconut pulp, HCl activating agent, aluminum foil, filter paper and distilled water.

Coconut pulp was prepared from the coconut milk manufacturing site and the coconut pulp was cleaned of dirt, then dried using an oven at 105ºC for 2 hours. The dried coconut pulp was carbonized using a furnace at 300ºC with time variations of 10 minutes, 15 minutes, and 20 minutes. Carbonized carbon was characterized by carbon yield. Then the carbonized carbon was pulverized using a mortar and pestle and filtered using a 120 mesh sieve [1]. The refined carbon was activated with 0.5 M HCl (1:10) as much as 25 grams for 24 hours. After activation, the sample was filtered and washed with distilled water until the ph of the sample was the same as distilled water, then the sample was oven at 105ºC for 2 hours [10]. After that, the samples were characterized by testing water content, ash content, steam content, and bound carbon content. Then the sample was characterized by XRD.

Characterization of coconut pulp carbon is done by calculating the yield value of carbon. The test was carried out by weighing 100 grams of dried coconut pulp and then carbonized with a set temperature and time. Carbonized carbon is weighed using a balance sheet. To find out the yield value is calculated using the following equation :

$$Carbon\ Yield(\%) = \frac{a}{b} \times 100\% \quad (1)$$

Description:
a : Carbon weight (g)
b : Initial weight of coconut pulp (g) [11].

Testing the water content of activated carbon is done by weighing a sample of 1 gram, then baked at 105ºC for 1 hour. Enter the desiccator for 30 minutes to cool, then weigh using an analytical balance. To find out the water content is calculated using the equation :

$$Water\ Content(\%) = \frac{a - b}{a} \times 100\% \quad (2)$$

Description:
a : Initial weight of activated carbon (g)
b : Weight of activated carbon after drying (g) [1].

Testing the ash content of activated carbon is carried out by weighing a sample of 1 gram, then furnace at 700ºC for 1 hour. Enter the desiccator for 30 minutes to cool, then weigh using an analytical balance. To determine the ash content, it is calculated using the equation :

$$Ash\ Content\ (\%) = \frac{b}{a} \times 100\% \quad (3)$$

Description:
a : Initial weight of activated carbon (g)
b : Ash weight (g) [1].

Assessment of the vapor content of activated carbon is carried out by weighing a sample of 1 gram, then furnace with a carbonization temperature of +10ºC for 6 minutes. Enter the desiccator for 30 minutes to cool, then weigh using an analytical balance. To determine the vapor content is calculated using the equation:

$$Vapor\ Content = \frac{a-b}{a} \times 100\% \quad (4)$$

Description:
a : Initial weight of activated carbon (g)
b : Weight of activated carbon after heating (g) [1].

Bound carbon content is obtained from the subtraction of the part lost during heating in the vapor content and ash content tests. To determine the bound carbon content, the equation is used :

$$Fixed\ Carbon(\%) = 100\% - (A + B) \quad (5)$$

Description:
A: Ash content (%)
B : Vapor content (%) [1].

The test results of coconut pulp activated carbon will be compared with SNI Standard 06-3730-1995 as in Table 1:

Table 1. Quality Requirements for Indonesian Activated Carbon (SNI 06-3730-1995)

Test Types	Requirements
Water Content	Max 15 %
Vapor Content	Max 25%
Ash Content	Max 10%
Fixed Carbon	Max 65%

(Source: SNI 06-3730-1995 [1])

3. Results and Discussion

Coconut pulp that has been in the furnace at a temperature of 300 with a variation of carbonization time of 10 minutes, 15 minutes, and 20 minutes successfully became carbon, while for carbonization time of 5 minutes did not succeed in becoming carbon completely, because it was still in the form of dry brown coconut pulp. At this stage of carbonization, rendement has been carried out. The test was conducted to find out how much weight of carbon can be produced after carbonization of coconut pulp. The results of the coconut pulp carbon rendement can be seen in Table 2:

Table 2. Results of Coconut Pulp Carbon Yield

Carbonization Time (minutes)	Carbon Yield (%)
10	29,64
15	27.39
20	21,09

In Table 2, it shows that the highest carbon yield is carbon with a carbonization time of 10 minutes with a carbon yield of 29.16%, while for a carbonization time of 15 minutes the carbon yield is 27.39%, and a carbonization time of 20 minutes the carbon yield is 21.09%. From the results of this study that the best carbon yield is at a carbonization time of 10 minutes because it has the highest carbon yield. In previous research with palm shell carbon material [12], the best carbon yield was 40% at a carbonization temperature of 300ºC and a time of 1 hour.

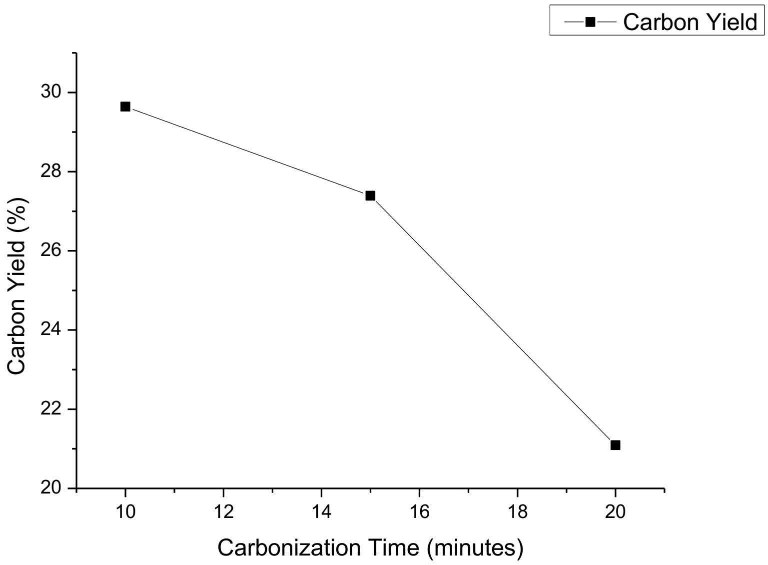


Figure 1. Graph of coconut pulp carbon yield results

In Figure 1, it shows that the carbon yield decreases with increasing carbonization time. This is supported by previous research using palm shell carbon material [12] and rice husk charcoal material [13], the carbon yield is getting less at longer carbonization times. The low charcoal yield is because the reaction between carbon and water vapor increases with increasing temperature and length of carbonization time, so that the carbon that reacts into CO2 and H2 becomes a lot, otherwise the amount of carbon produced is getting less.

Activated carbon that has been activated using HCl has been tested for water content, ash content, vapor content, and fixed karbon. Tests were carried out on activated carbon variations of carbonization time 10 minutes, 15 minutes, and 20 minutes to find out the best activated carbon from variations in carbonization time according to SNI 06-3730-1995 standards, which is max 15%.

Water content testing is done to determine the water content remaining in the carbon after the carbonization process. The results of the water content test can be seen in Table 3 :

Table 3. Test Results For Water Content of Coconut Pulp Activated Carbon

Carbonization Time (minutes)	Water Content (%)	Indicator
10	1,72	Meets the standard of SNI 06-3730-1995
15	2,01	Meets the standard of SNI 06-3730-1995
20	4,40	Meets the standard of SNI 06-3730-1995

In Table 3, the water content for all variations of carbonization time that has been tested meets the SNI 06-3730-1995 standard, which is max 15% and the best water content is obtained on activated carbon with a variation of carbonization time of 10 minutes because the lowest water content is 1.72%. In previous research using coconut shell material [14], the best water content was 1.01% at 2 hours carbonization time.

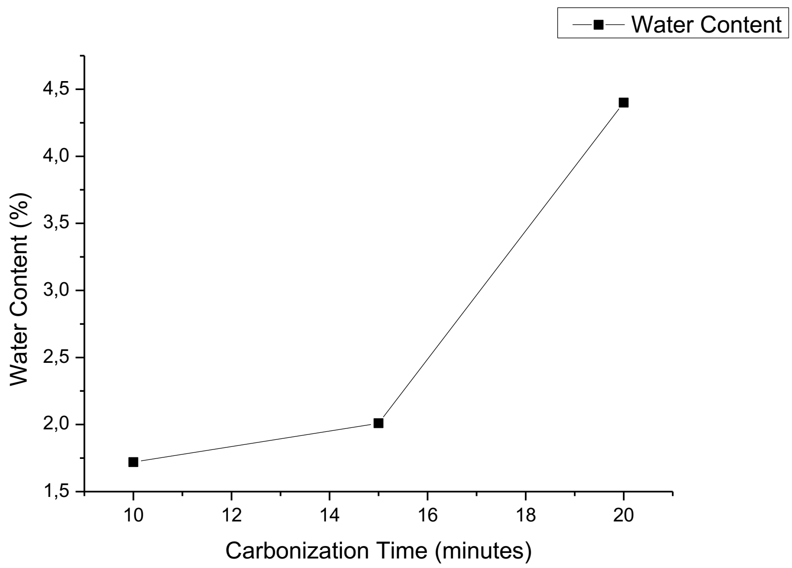


Figure 2. Graph of the test results of coconut pulp carbon water content

In Figure 2, the water content test results show an increase from the variation of carbonization time of 10 minutes, 15 minutes, and 20 minutes. From the test, it was found that the longer the carbonization time, the water content of the activated carbon will increase. Based on previous use of coconut shell [14] and rice husk charcoal material [13], there was some increase in moisture content at various times. This is because the longer the carbonization time, the pores of the charcoal will be more open, so that when moving the charcoal from the furnace to the desiccator and weighing tools, there is direct contact between the charcoal which is hygroscopic with air so that the charcoal absorbs a lot of water vapor. The longer the carbonization time, the more open the carbon pores are so that they absorb a lot of water vapor. This can also be caused by the drying process that is done not perfect so that water molecules have not evaporated to the maximum.

Vapor content testing is done to find out many substances or compounds that have not evaporated in the carbonization process. The results of the vapor content test can be seen in Table 4:

Table 4. Test Results for Vapor Content of Coconut pulp Activated Carbon

Carbonization Time (minutes)	**Vapor Content (%)**	**Indicator**
10	8,54	Meets the standard of SNI 06-3730-1995
15	10,47	Meets the standard of SNI 06-3730-1995
20	13,08	Meets the standard of SNI 06-3730-1995

In Table 4, the vapor content for all variations of carbonization time that has been tested meets the SNI 06-3730-1995 standard, which is max 25% and the best vapor content is obtained on activated carbon with a variation of carbonization time of 10 minutes because the lowest vapor content is 8.54%. In previous research using coconut shell material [14], the best vapor content was 52.08% at 4 hours carbonization time.

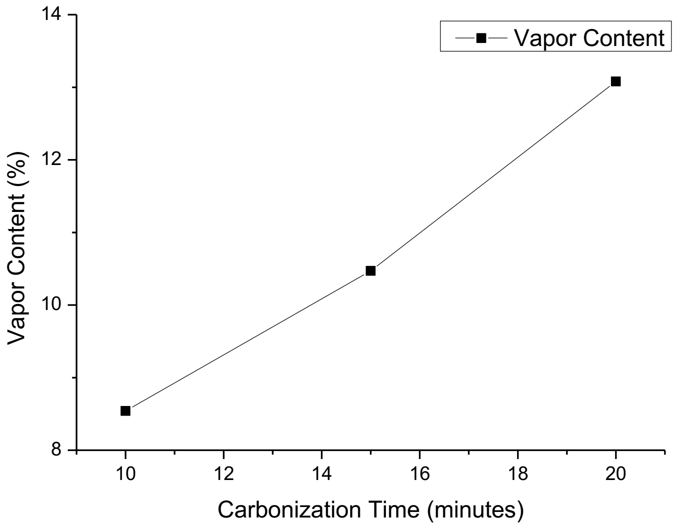


Figure 3. Graph of the test results of coconut pulp carbon vapor content

In Figure 3, the results of the vapor content test also show an increase from the variation of carbonization time of 10 minutes, 15 minutes, and 20 minutes. From the test, it is obtained that the longer the carbonization time, the vapor content of the activated carbon will increase. Based on previous research using coconut shell [14] and rice husk charcoal material [13], there is an increase in vapor content in several increases in carbonization time. The high vapor content is due to the surface of the activated activated carbon containing vaporized substances contained from the interaction between carbon and water vapor. This can reduce its absorption of gases or solutions. This is also caused by the higher water content so that the level of vaporized substances obtained is also higher.

Ash content testing is carried out to determine the content of metal oxides that are still present in activated carbon after the carbonization process. The results of the ash content test can be seen in Table 5:

Table 5. Results of Ash Content Testing of Coconut Pulp Activated Carbon

Carbonization Time (minutes)	**Ash Content (%)**	**Indicator**
10	0,81	Meets the standard of SNI 06-3730-1995
15	0,65	Meets the standard of SNI 06-3730-1995
20	0,55	Meets the standard of SNI 06-3730-1995

The ash content for all variations of carbonization time that have been tested is in accordance with SNI standards, which is max 10% and the best ash content is obtained on activated carbon with a carbonization time variation of 20 minutes because the lowest ash content is 0.55%. In previous research using coconut shell material [14], the best ash content was 1.01% at a carbonization time of 2 hours.

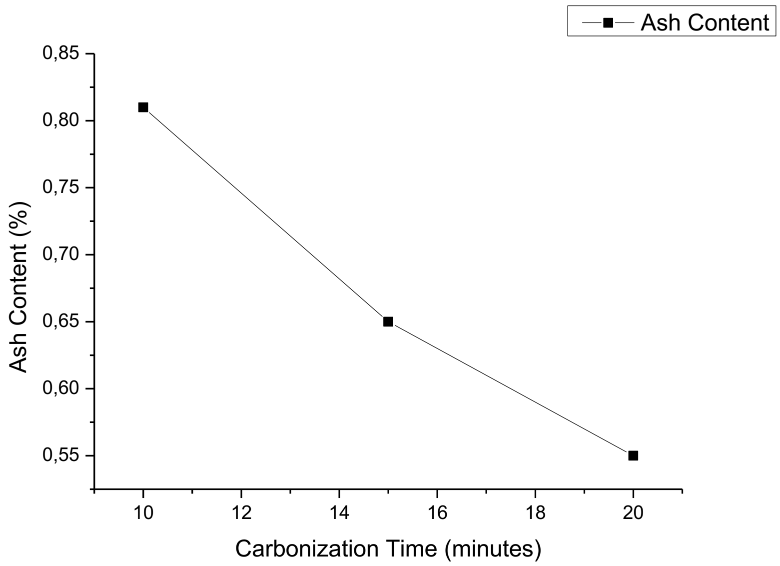


Figure 4. Graph of the test results of coconut pulp carbon ash content

In Figure 4, the ash content test results show a decrease from the variation of carbonization time of 10 minutes, 15 minutes, and 20 minutes. From the test, it was found that the longer the carbonization time, the ash content of the activated carbon will decrease. Based on research on banana peel carbon black at temperatures of 500°C, 1000°C, 1500°C and times of 2 hours, 4 hours and 6 hours [15] and on nipah shell charcoal [16], the ash content obtained decreases. This is because the longer the carbonization time, the more unwanted substances are destroyed or lost, thus reducing the ash ratio.

The bound carbon content test was conducted to determine the carbon content after the carbonization process. Bound carbon content was calculated from the vapor content and ash content. The test results of bound carbon content can be seen in Table 6 :

Table 6. Test Results of Bound Carbon Content of Coconut Pulp Activated Carbon

Carbonization Time (minutes)	Fixed Carbon (%)	Indicator
10	90,65	Meets the standard of SNI 06-3730-1995
15	88,88	Meets the standard of SNI 06-3730-1995
20	86,37	Meets the standard of SNI 06-3730-1995

In Table 6, the bound carbon content for all variations of carbonization time that has been tested meets the SNI 06-3730-1995 standard, namely min 65% and the best bound carbon content is obtained on activated carbon with a variation of carbonization time of 10 minutes because the content of the highest bound carbon content is 90.65%. In previous research using coconut shell material [14], the best bound carbon content was 46.88% at 4 hours carbonization time.

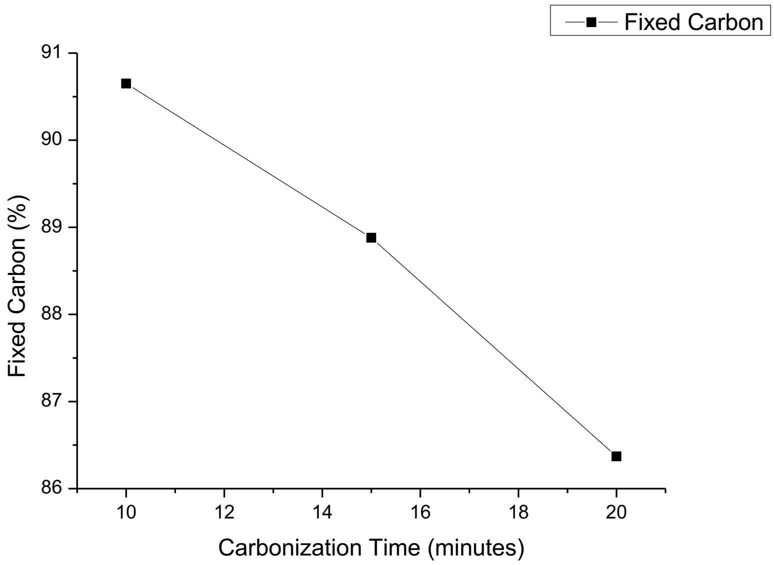
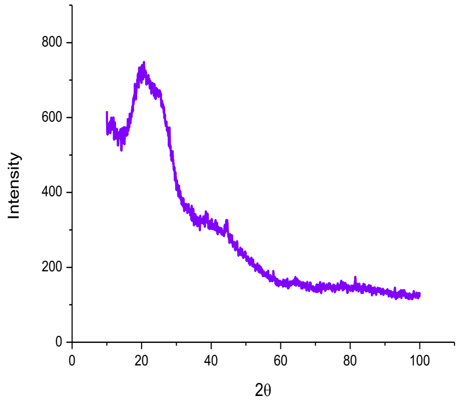
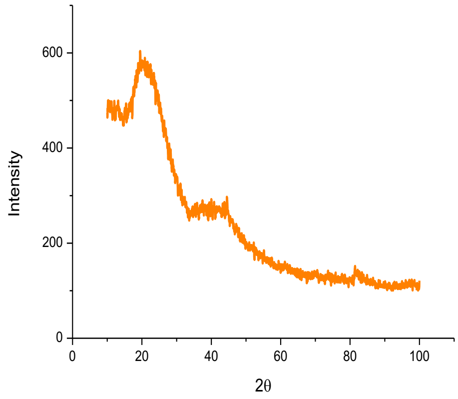


Figure 5. Graph of the test results of coconut pulp carbon bonded carbon content

In Figure 5, the test results of bound carbon content show a decrease from the variation of carbonization time of 10 minutes, 15 minutes, and 20 minutes. From the test, it is obtained that the longer the carbonization time, the bound carbon content of activated carbon will decrease. Based on research on coconut shell activated carbon at 225ºC, 250ºC, 275ºC, 300ºC, 325ºC, 350ºC and time 1, 2, 3, 4, 5, 6, 7 hours [14] and on nipah shell charcoal [16], the bound carbon content obtained is decreasing. This is due to the high temperature and time in carbonization resulting in damage to the carbon plates, due to excessive oxidation. Increased oxidation power, both by high temperatures and by oxidizing gases will cause damage to the pore wall, so that the surface area of the pore wall will decrease and the carbon content obtained is smaller. This is also caused by the lower ash content obtained so that the inorganic substance content is higher and the bound carbon content is lower.

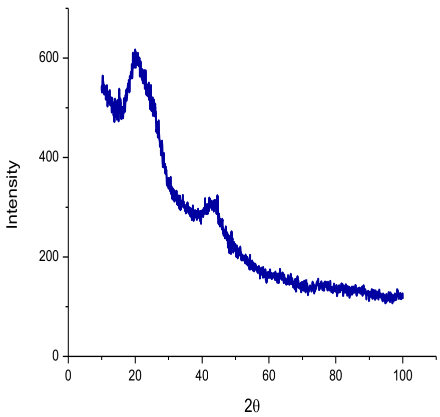
XRD (X-ray diffraction) test on activated carbon is done to determine the crystal structure of activated carbon. The results of XRD characterization of activated carbon can be seen in Figure 6 :

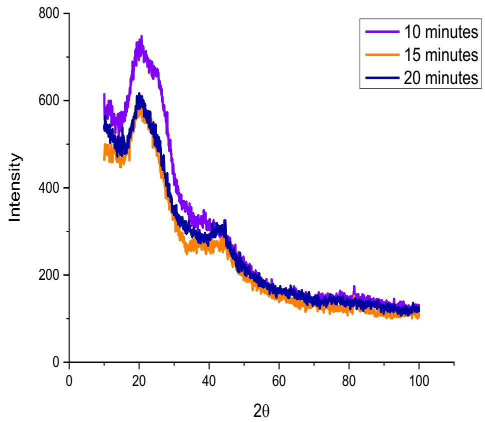




(a)

(b)





(c)

(d)

Figure 6. (a). XRD characterization results of activated carbon variation of carbonization time 10 minutes, (b). XRD characterization results of activated carbon variation carbonization time of 15 minutes, (c). XRD characterization results of activated carbon variation carbonization time 20 minutes, (d). XRD characterization results of activated carbon variation of carbonization time 10, 15, and 20 minutes

In Figure 6, the XRD results show that the diffraction intensity is relatively small and has no sharp or pointed peaks indicating an amorphous activated carbon structure. In Figure (a) the diffractogram pattern of the results of XRD analysis of activated carbon with a carbonization time of 10 minutes there are two diffraction peaks that appear on activated carbon, namely at 2θ = 20.070º and 44.454º. In figure (b) the diffractogram pattern of the results of XRD analysis of activated carbon with a carbonization time of 15 minutes there are two diffraction peaks that appear on activated carbon, namely at 2θ = 20.765º and 44.569º. In Figure (c) the diffractogram pattern of the results of XRD analysis of activated carbon with a carbonization time of 20 minutes there are two diffraction peaks that appear on activated carbon, namely at 2θ = 21.012º and 44.720. The shift of 2θ to a smaller direction indicates that the pores of activated carbon at a carbonization time of 10 minutes are larger [17]. The longer the carbonization time, the lower the intensity obtained, thus indicating an increasingly irregular crystal shape and atomic arrangement. The results of this XRD test are in accordance with previous research [1], the XRD results in the study showed that activated carbon does not have a specific peak because activated carbon is an amorphous material. An irregular crystal arrangement can inhibit heat transfer and produce low thermal conductivity, so it can be used as a thermoelectric manufacturing material. One of the requirements for materials that can be used as thermoelectric materials is to have low thermal conductivity.

4. Conclusion

Based on the research that has been done, it can be concluded that the optimization of carbonization time on coconut pulp activated carbon for thermoelectric materials is 10 minutes. The test results show that based on SNI 06-3738-1995 the lowest water content, lowest vapor content, and highest bound carbon content is at a carbonization time of 10 minutes, while the lowest ash content is at a carbonization time of 20 minutes. because the most meet the requirements is at a carbonization time of 10 minutes, the optimum time of carbonization of coconut pulp activated carbon is 10 minutes. The test results of activated carbon variations in carbonization time of 10 minutes, 15 minutes and 20 minutes, all meet the SNI 06-3730-1995 Standard. XRD results show that the longer the carbonization time, the intensity decreases with the 2θ angle shifting to the left. In this study, the expected moisture content, vapor content, ash content is the lowest and the highest bound carbon content.

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